Double SiPM readout layers for Sc-ECAL prototype

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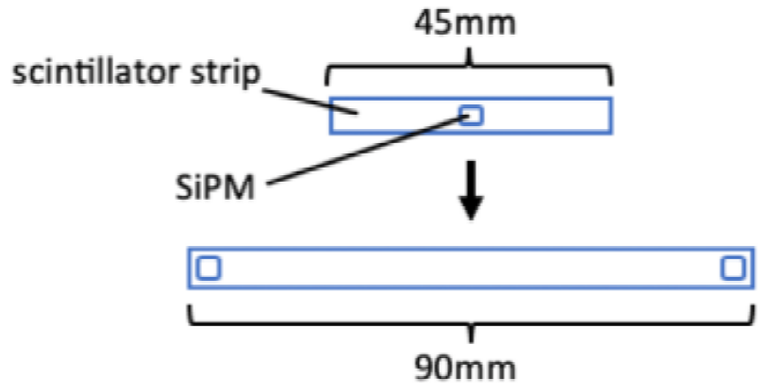
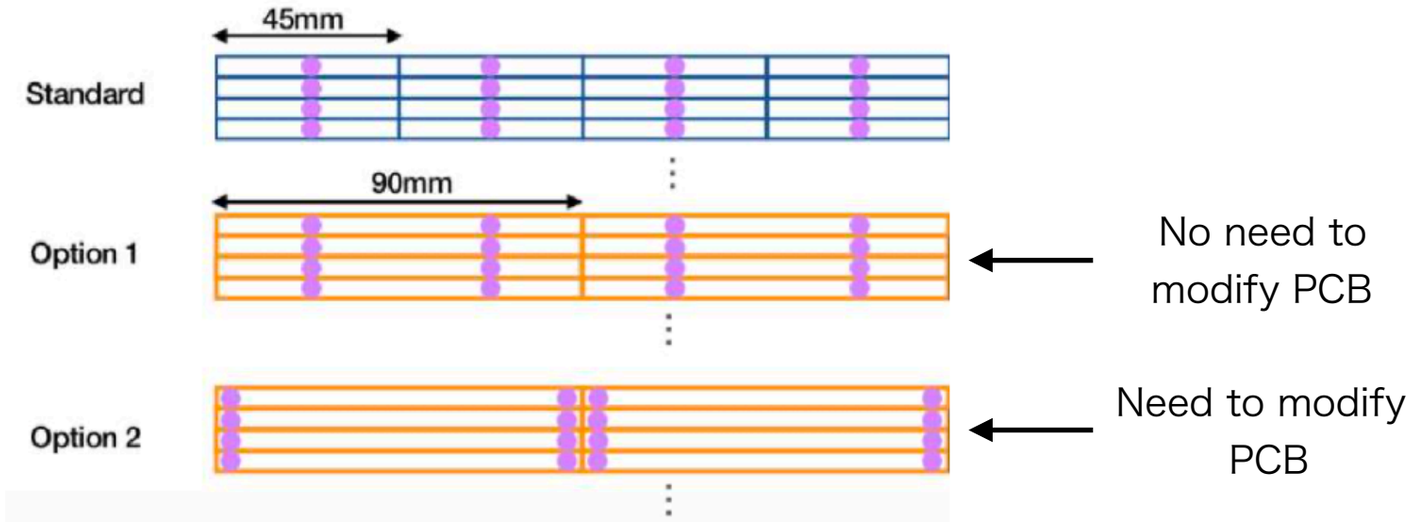
Double SiPM readout (reminder)

- Readout by 2 SiPMs at strip ends
- Twice longer strip (L=90mm) to keep the number of SiPMs
- Possible advantages
  - Eliminating noise by taking coincidence
  - Higher light yield by summing 2 SiPM readouts
  - Even lower light yield for each SiPMs (→less saturation)
  - Position reconstruction by charge and/or timing difference between two readouts (→ reduce ghost hits)

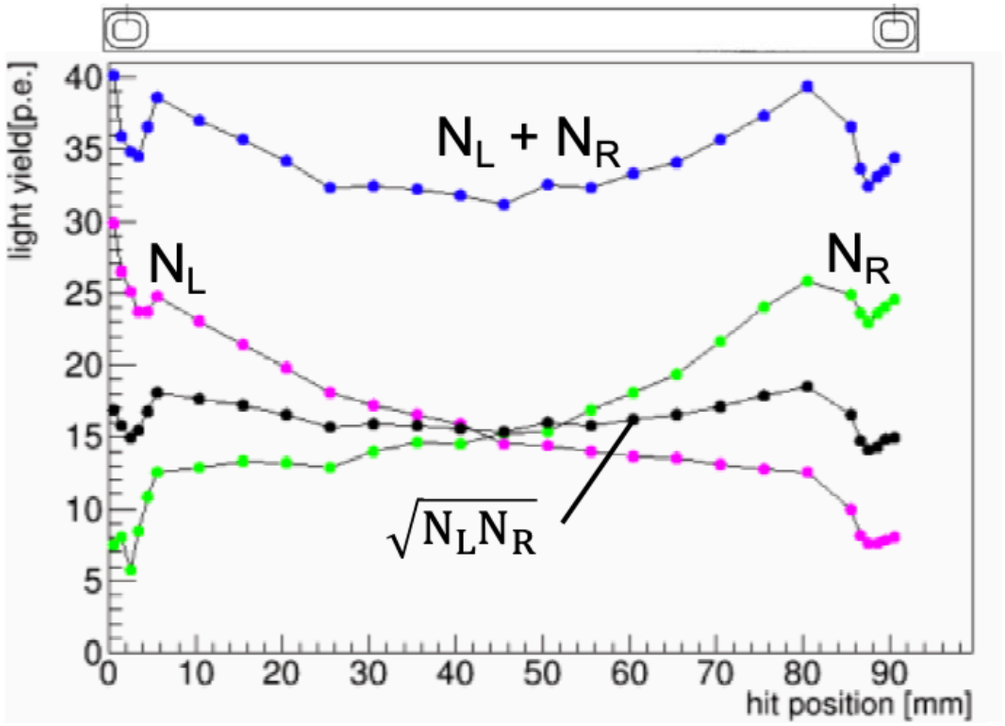


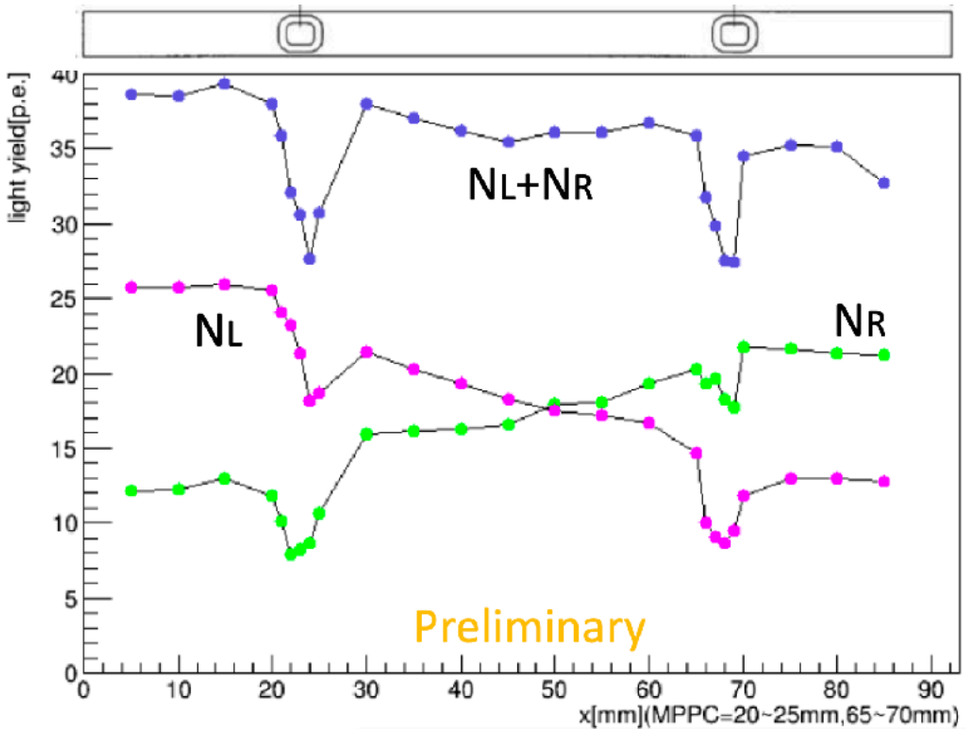
- Two detection layers with double SiPM readout will be added to Sc-ECAL prototype (See talk on CEPC Sc-ECAL by Jianbei)
  - Two possible implementations → option 1 adopted
  - Noise reduction by taking coincidence in offline analysis → need dedicated low threshold run



Performance test

- Two SiPMs strip end
  - More or less flat response with sum of two readouts
  - Larger light yield (~35 p.e.) than 45mm strip (~27 p.e.)
  - Position-dependent N_{pe} for each MPPC readout
    - Possibility of position reconstruction using charge and timing
- Two SiPMs in middle of strip
  - More or less flat response with sum of two readouts
  - Larger light yield (~35 p.e.) than 45mm strip (~27 p.e.)
  - No position dependence outside dimples
    - No chance of position reconstruction outside dimples





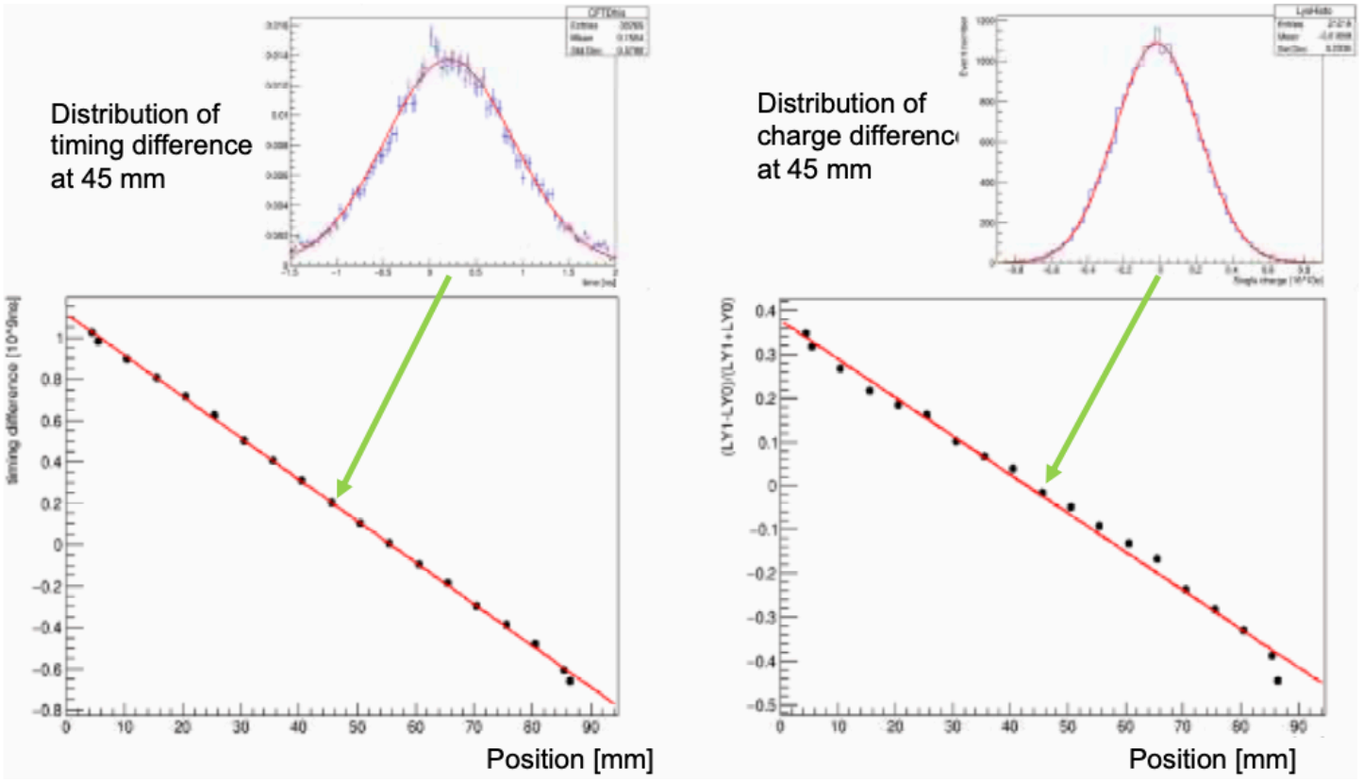
Position reconstruction

- Position reconstruction from weighted mean for charge and timing difference

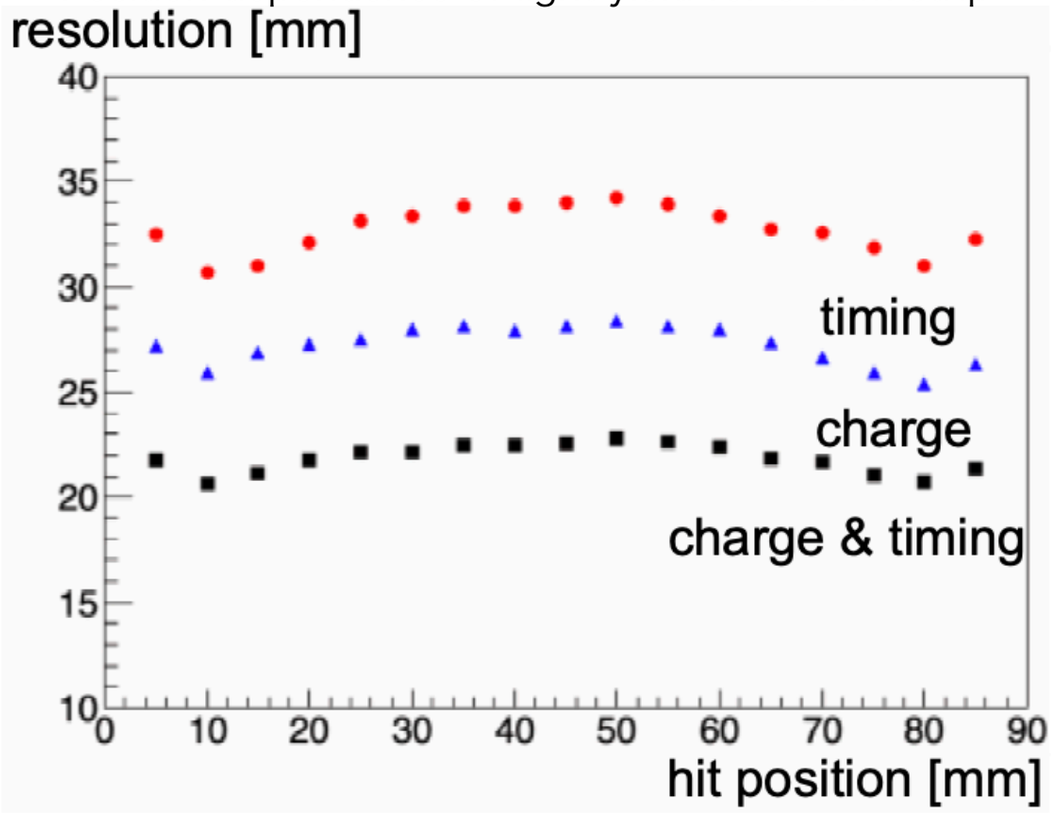
$$X = \frac{\frac{x_{\text{charge}}}{\sigma^2_{\text{charge}}} + \frac{x_{\text{time}}}{\sigma^2_{\text{time}}}}{\frac{1}{\sigma^2_{\text{charge}}} + \frac{1}{\sigma^2_{\text{time}}}}$$

- σ~20mm was obtained with combined reconstruction
  - The achieved resolution is not too bad
  - The effect in calorimeter performance to be studied by MC simulation

Position dependence of charge (left) and timing (right) difference

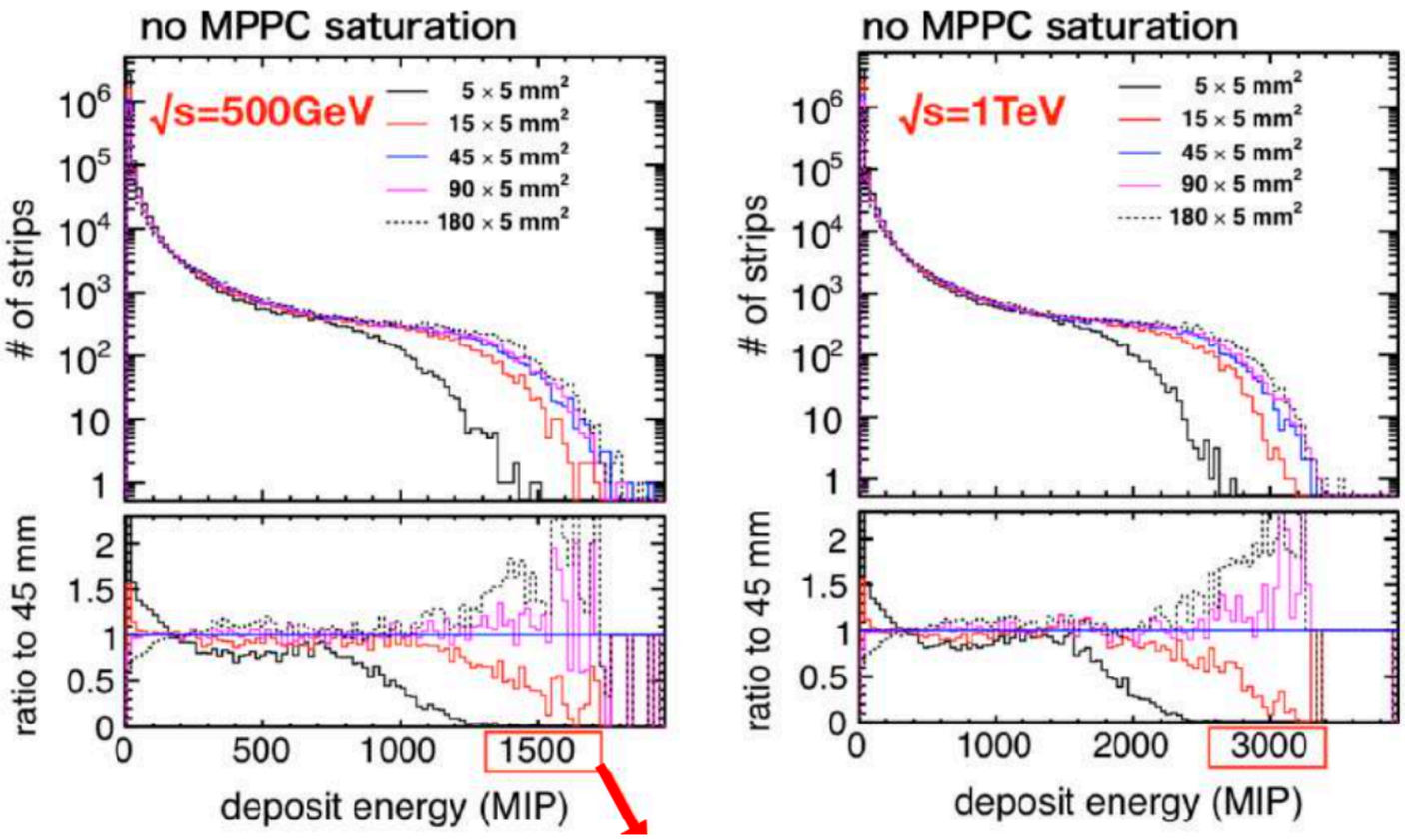


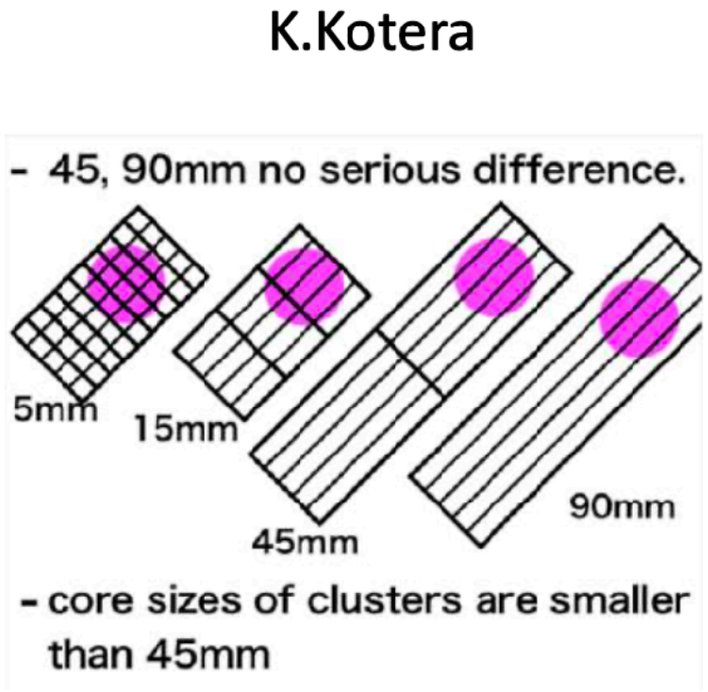
Position dependence of light yield for 90mm strip



SiPM saturation with Longer Strip

- Previous MC study done by Shinshu University
  - Considering Bhabha events at √s=500 GeV & 1 TeV

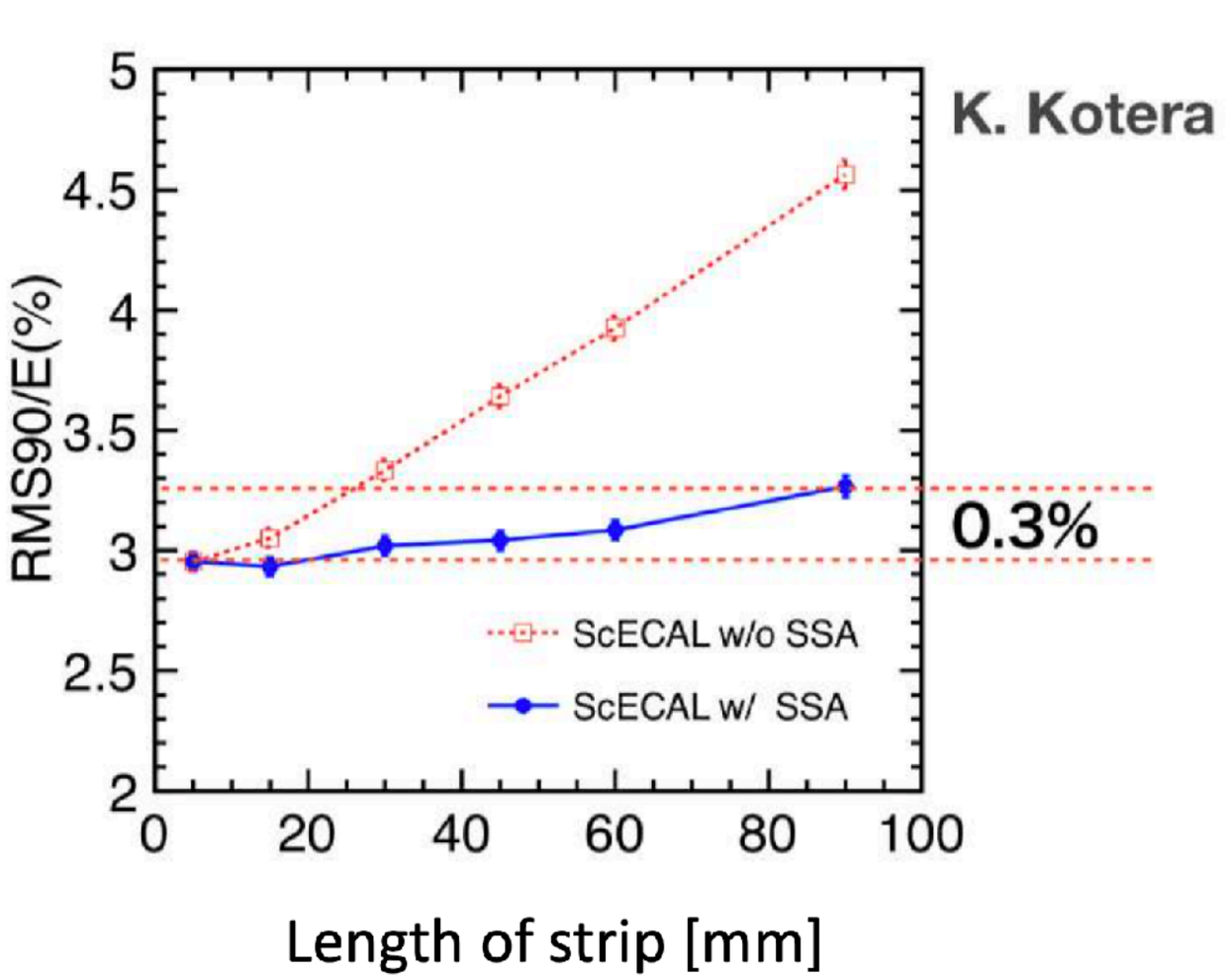




- No significant difference at longer strip
  - Cluster size is smaller that strip length
- Saturation not worsened with longer strip

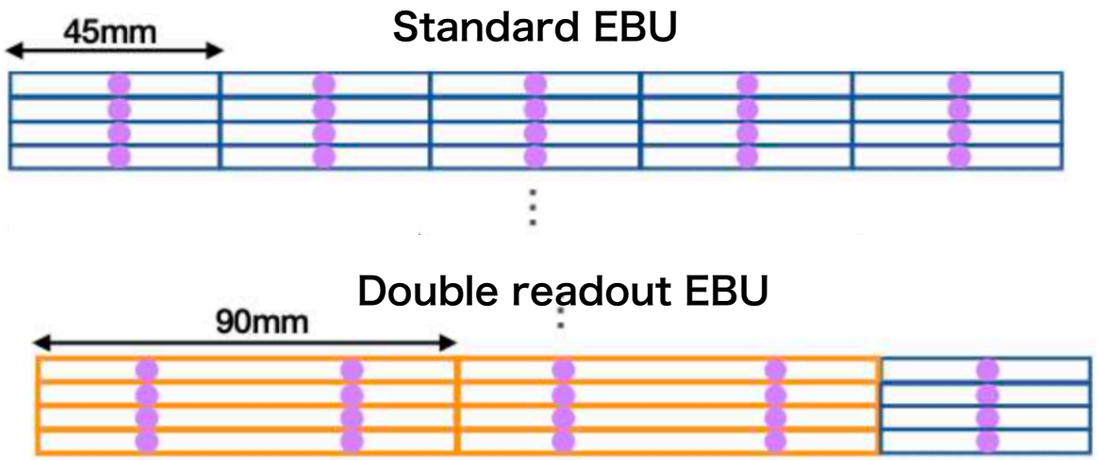
Jet energy resolution with longer strip

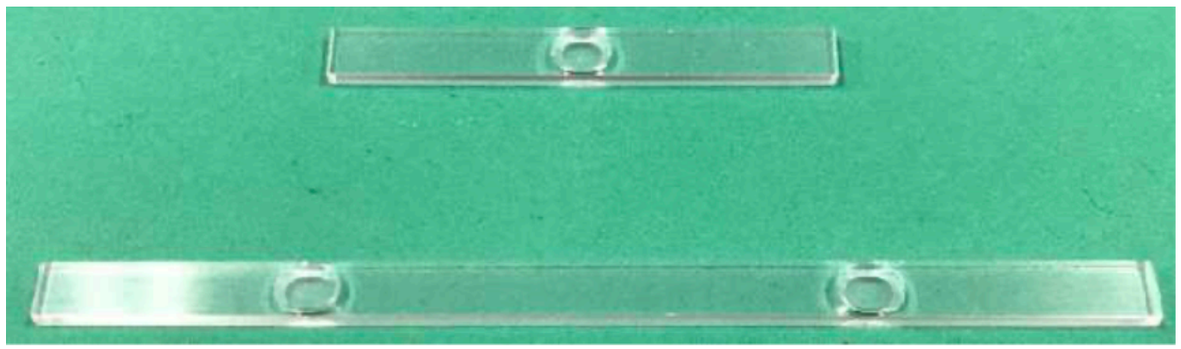
- Previous MC study done by Shinshu group
- JER slightly worsened for longer strip due to ghost hits and pile-up
- N.B. not taken into account possible improvements with double readout
  - Noise reduction by coincidence
  - Position reconstruction
- Planned simulation study to see the effect of double readout



Production of scintillator strips for double readout layer

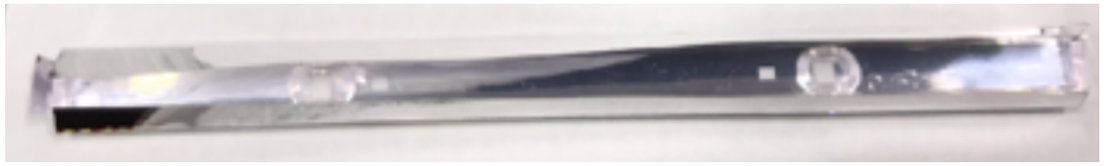
- **SiPM cavities in the middle of the strip (option1)**
  - Implementation with minimal modifications using standard EBU
  - Designs of strips and reflectors are the same as the standard EBU configuration
- **200 × 90mm strips** and **100 × 45mm strips** were produced
  - 5 rows of 45mm strips at 1 line for the standard configuration
  - 90mm + 90mm + 45mm at 1 line for the DR layer
- Scintillator strips produced by injection moulding
  - Injection moulding would be the only possibility for the large scale production
  - Production of large 2mm-thick plate by injection moulding → machining (strip shape + cavity)
  - Foreseen lower light yield compared to commercial PVT scintillator
  - Light yield test done

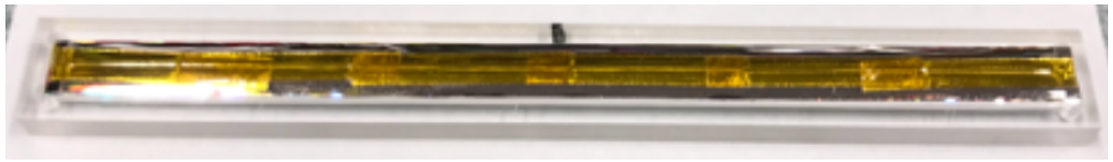




Reflector wrapping (90mm strip)

- Wrapping by hand with a help of jig



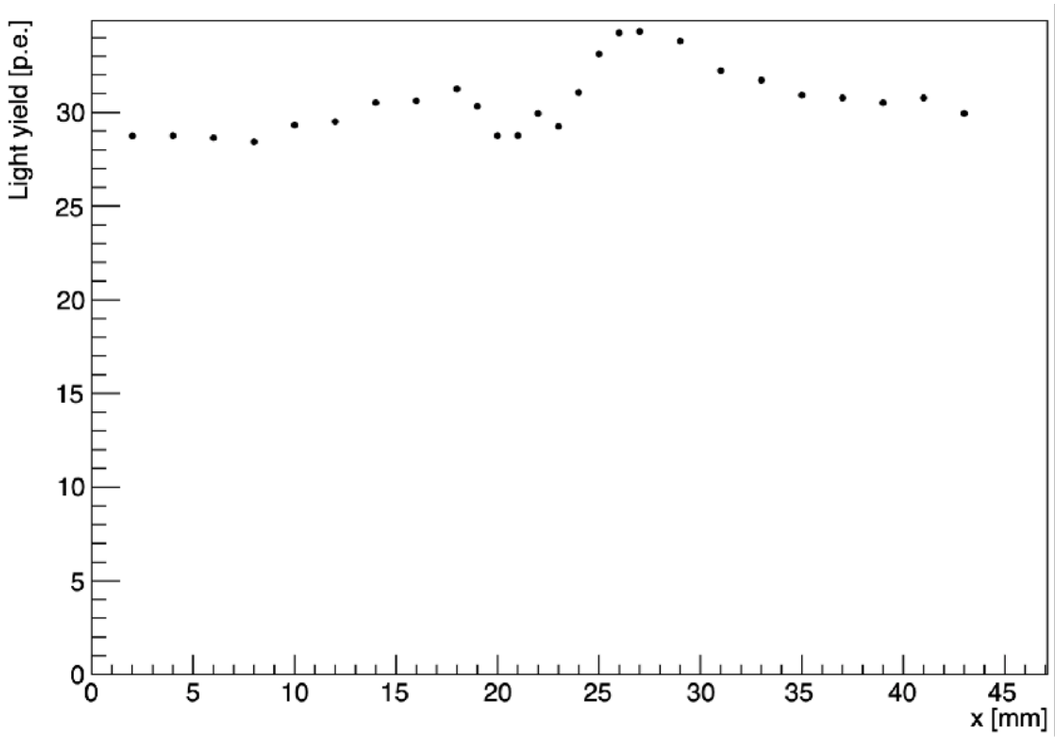


Light yield test

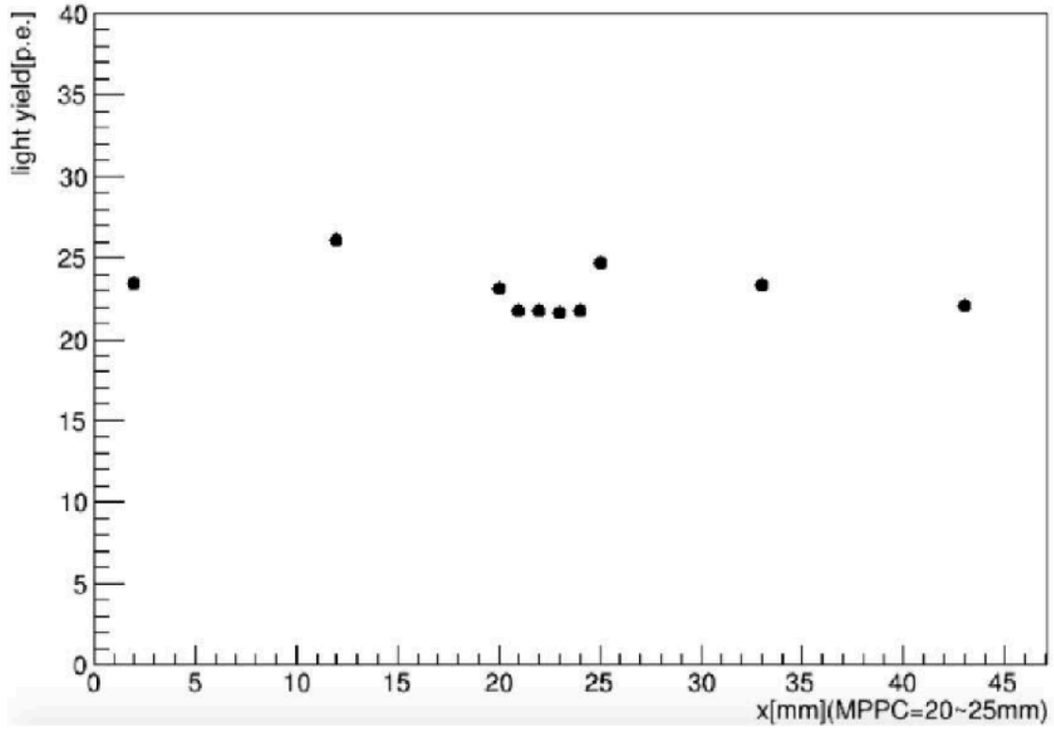
- LY of strip produced by injection moulding is lower by ~20% compared to the standard 45mm strip produced by China

  → Still sufficient light yield

Standard 45mm strip for Sc-ECAL prototype

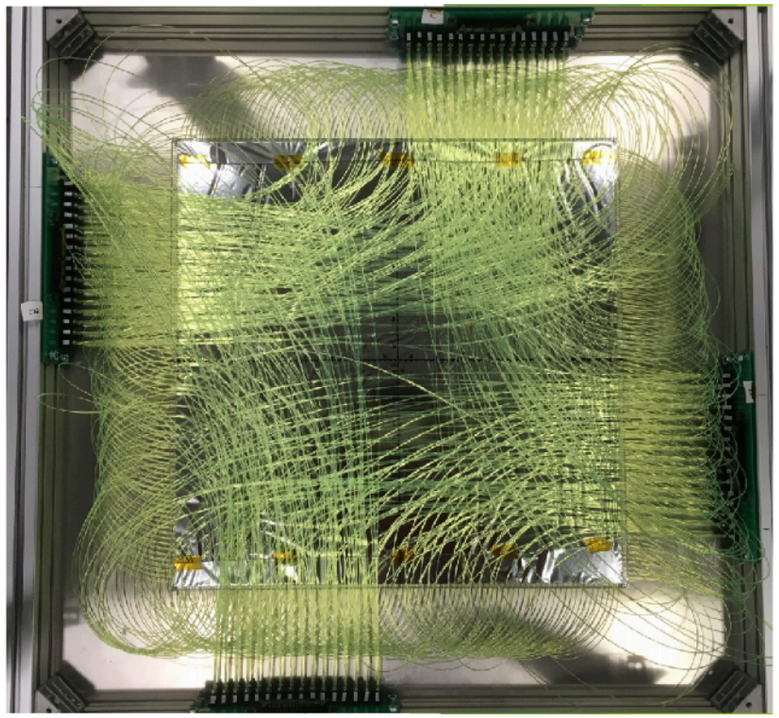


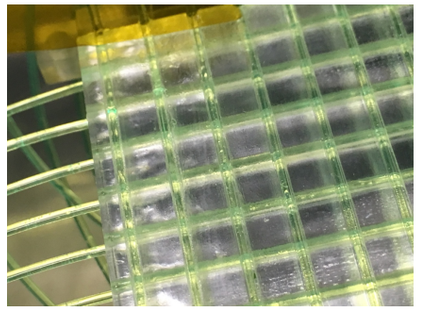
45mm strip produced by injection moulding

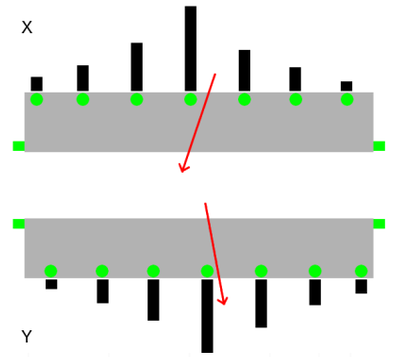


Cosmic-ray hodoscopes

- CR hodoscopes were developed and commissioned at DESY in 2017
  - Use CR test for AHCAL larger prototype
  - See the proceedings at PD18 for details : https://doi.org/10.7566/JPSCP.27.012009
- To be used at CR test of the detection layers for Sc-ECAL prototype

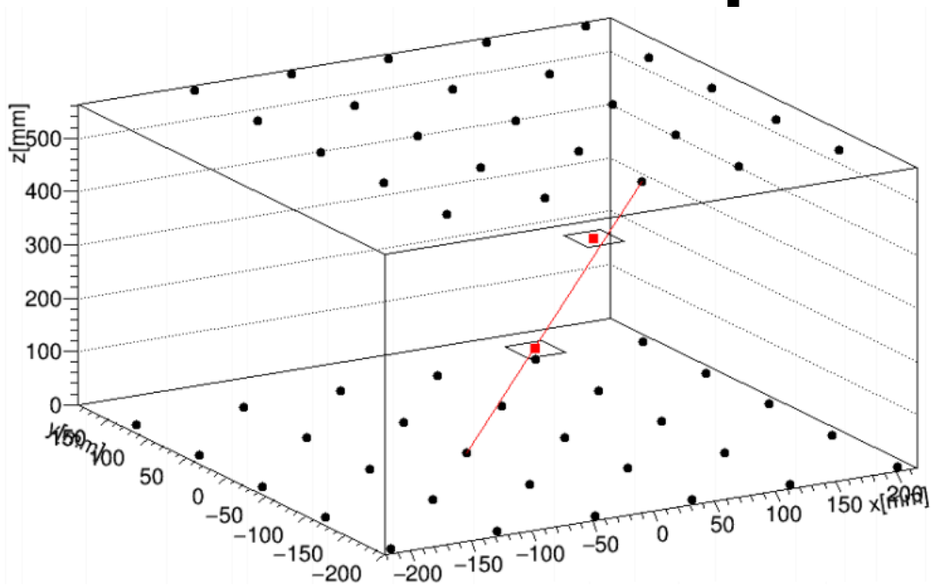






- Now preparing the shipment from UTokyo to USTC

- DAQ system for EBUs is based on FELIX, while hodoscope DAQ is based on EASIROC module
  - The synchronisation between 2 system is needed
  - EUDAQ framework can be used to operate 2 system simultaneously
  - EUDAQ producers under dvelopment



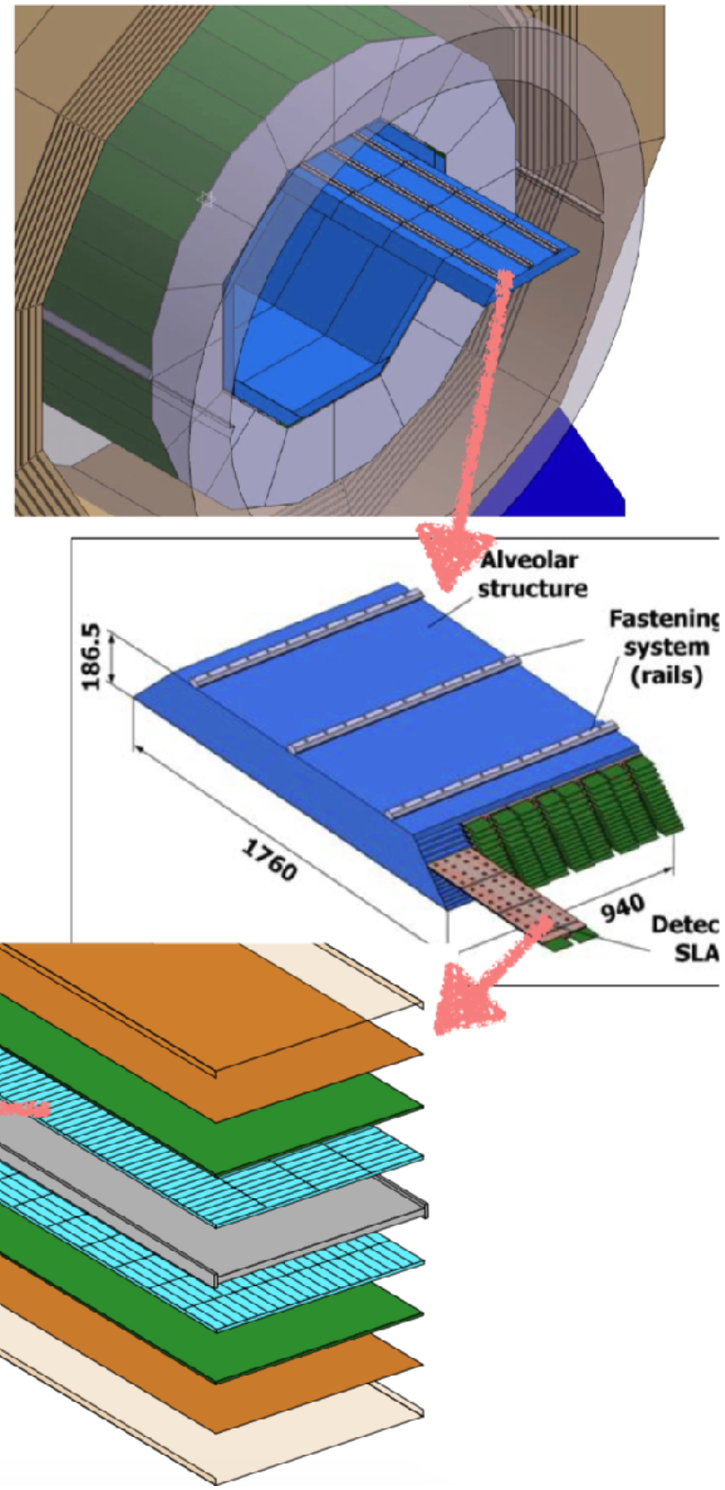
Summary and Prospects

- New readout method with double SiPM proposed to improve the performance of scintillator strip for Sc-ECAL
- Good performance of double readout strip demonstrated in lab. test
- Two detection layers with double SiPM readout will be installed to Sc-ECAL prototype
  - In preparation for test beam at DESY in Aug. 2020
  - Status
    - Soldering of SiPMs on double readout EBUs was completed
    - Scintillator strips wrapped with ESR are on the way to China
    - Strip assembly on EBU will be done at a Chinese company in March
    - The commissioning will be done together with the standard layers in China in March and April
      - Calibration using position-sensitive cosmic-ray hodoscopes
    - Test beam at DESY in August, 2020

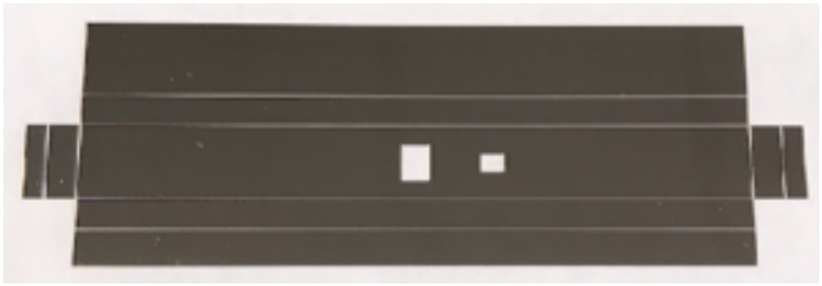
Backup

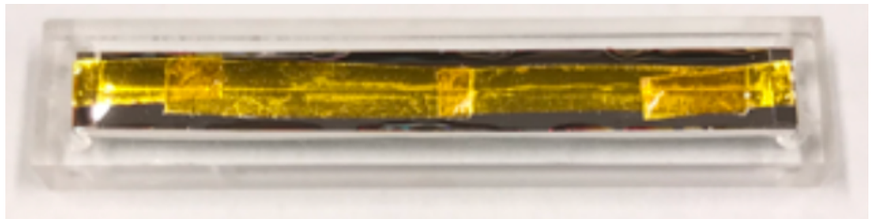
Sc-ECAL (reminder)

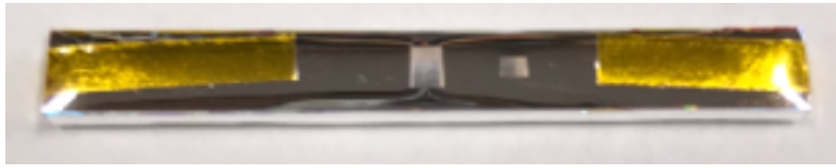
- Scintillator Electromagnetic CALorimeter (Sc-ECAL)
  - Technology option of EM calorimeter for ILD
- Based on scintillator strips readout by SiPM
  - 5 × 45 × 2 mm scintillator strip
- Virtual segmentation : 5mm × 5mm with strips in x-y configuration
- Timing resolution < 1 ns
- Low cost



Reflector wrapping (45mm strip)







Reflector wrapping (90mm strip)